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Influence of Packaging and Storage Time on Aroma Compounds of Minimally Processed Lettuce

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Abstract

This study investigates the changes in aroma compounds of minimally processed lettuce as a function of packaging and storage time. In order to achieve this, a detailed experimental study was performed on iceberg lettuce variety *Bernardinas* which was lightly processed and packaged in two different packaging films and stored at 5 °C for 11 days. Changes in gas composition and volatile compounds were assessed. It is concluded that volatiles of minimally processed lettuce are influenced by packaging film and storage period, where the formation of off-odor limited the shelf-life of the product.

Introduction

Iceberg lettuce (*Lactuca sativa* L.) is one of the most popular ready-to-eat vegetables. Minimally processed products lettuce have a short shelf-life due to rapid loss of freshness. Modified atmosphere packaging (MAP) has showed to be effective to increase the shelf-life of fresh-cut lettuce using an atmosphere of 1-5% oxygen (O₂) and 5-20% carbon dioxide (CO₂) combined with low temperature of storage [1]. However, extremely low O₂ (<1%) and high CO₂ levels (>20%) can cause off-odor shortening storage life of the product [1]. The aim of this study is to investigate the changes in aroma compounds of minimally processed lettuce as a function of packaging and storage time.

Experimental set up

Iceberg lettuce variety *Bernardinas* was harvested in September 2009 by local grower in Bogense, Denmark and minimally processed by Gasla Odense. Two-hundred and fifty grams of minimally processed lettuce were packaged in two different films: OPALEN 65 AF (Film 1) and OPP/PE L 2040 AF (Film 2). Those films are used by commercial processors in Denmark. All treatments were made in duplicate and stored at 5 °C for 11 days. Changes in CO₂ and O₂ in the packages were measured using a gas analyzer at 1, 5, 8 and 11 days of storage. The volatiles were analyzed after 1 and 11 days of storage using dynamic headspace sampling. GC-MS was used for the separation and identification of the aroma compounds. Volatile peak area was calculated on the basis of single ions and their concentration expressed as relative area.



Results and Discussion

Atmosphere analyses

A similar content of carbon dioxide and oxygen was found between F1 (Film 1) and F2 (Film 2) after 1 day of storage with 14 % O₂ and 5% CO₂ (Fig.1). As storage time increased, the accumulation of CO₂ and depletion of O₂ increased. F1 and F2 showed injurious CO₂ and O₂ levels at 11 days of storage. CO₂ content in F1 was 27%, nearly 2 times that of the content in F2. Oxygen content was below 0.05% at the end of the storage period. Accumulation of CO₂ in F1 over the storage period was possible due to film permeability. Extremely high CO₂ levels (>20%) and low O₂ (<1%) in packaged lettuce can cause anaerobic respiration [1]. Under this context, off-odors were easily detected once the packages were opened, being more severe in F1.

Aroma compounds

A total of 41 aroma compounds were identified in the study. Volatiles were mainly aldehydes (14), alcohols (9), terpenes (6), ketones (5), ester (2) and others. Figure 2 and 3 shows the score and loading plots, respectively. PC1 clearly discriminates between storage time, meanwhile PC3 separates packaging films (Fig. 2). Lettuce packaged in F2 at 1 day of storage was related with higher amount of cis-3 hexenol, which has been indicated as key aroma in lettuce [2]. Ethyl formate, ethyl acetate, 3-hydroxy butanone and 2,3-butanedione were associated with F1 at 11 days of storage (Fig. 3). Those compounds are characteristic of anaerobic respiration [1,3]. MAP and storage time can influence on the volatiles of commodities allowing the formation of desirable aroma but also on the development of off-odors, as exhibited in this study [1].

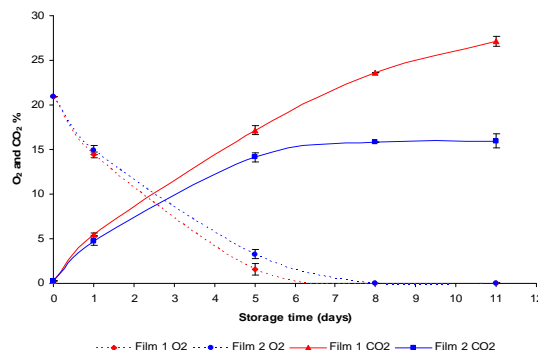


Figure 1. O₂ and CO₂ concentration of cut lettuce stored in two different packaging films at 5 °C for 11 days.

Table 1. Aroma compounds of lettuce with significantly higher relative areas ($p < 0.05$)

Interaction	Main effect
Day 11*Film1	Day 11
2-Methylbutanal	2-Methoxy-3-isopropyl pyrazine *
3-Methylbutanal	trans-2-Hexenal*
β-elemene	Ethyl formate
β-selinene	3-Hydroxy-2-butanone
2,3-Butanedione	
Ethyl acetate	

* = Key aroma of lettuce

In Table 1 the effect of film and storage time on selected aroma compounds is shown. Significantly higher relative areas of ethyl acetate and 2,3-butanedione in F1 after 11 days of storage could indicate that this film caused a higher formation of off-odor in lettuce than F2, due to critical accumulation of CO₂ and O₂ depletion. Under anaerobic atmosphere at 11 days of storage some compounds that contribute to the characteristic aroma in lettuce (trans-2 hexenal and 2-methoxy-3-isopropyl pyrazine) may become an off-odor in higher concentrations [2,4]. On the other hand, F2 showed significantly higher relative area of cis-3 hexenol at 1 day of storage with tendency to reduce after 11 days. Anaerobic respiration can also cause the decrease of key aroma in horticultural products [1].

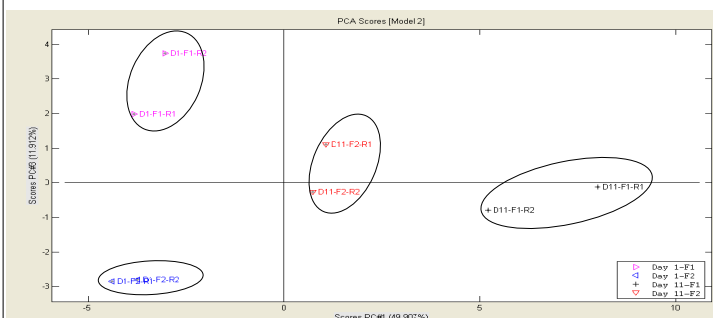


Figure 2. Score plot of minimally processed lettuce packaged in two different films at 1 and 11 days of storage (F1= Film 1, F2= Film 2, D1=Day 1 of storage, D11=Day 11 of storage).

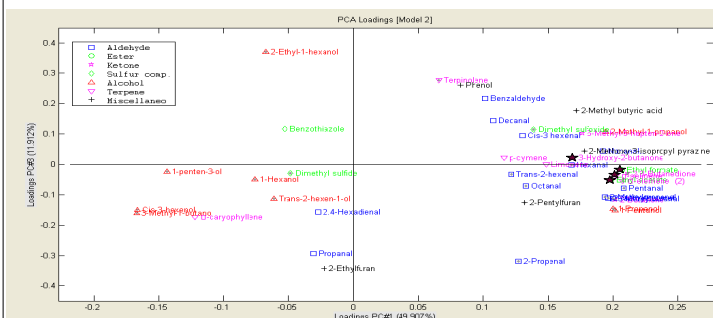


Figure 3. Loading plot of minimally processed lettuce packaged in two different films at 1 and 11 days of storage (★=Ethyl formate, ethyl acetate, 3-Hydroxy butanone and 2,3-butanedione).

Conclusion

- The shelf-life of packaged lettuce is limited by the formation of off-odor.
- Lettuce packaged in Film 1 develops a severe formation of off-odor at the end of the storage period.
- The aroma compounds of minimally processed lettuce are influenced by the packaging film, gas composition inside the package and storage time.

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